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13. ABSTRACT *(Maximum 200 words)*

This report documents the final progress of the one year grant covering the period Aug. 1998 - Aug. 1999. The aim of the project research was to develop a practical, formal methods-based enabling technology for advanced system design. An approach based on combining Petri net modeling and object-oriented design was investigated. The approach shows promise for supporting the design of distributed object software systems. Our major focus of work was to define a new type of object-oriented Petri net model, called a State-Based Object Petri Net (SBOPN). Techniques to incorporate object features such as encapsulation and instantiation were considered. In addition, a form of inheritence modeling was developed and formalized.

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Final Progress Report

Statement of the Problem Studied

This one-year project studied the use of a formal method to support the design and analysis of concurrent software. Although there are many clear benefits from using formal methods in software development, a common, major impediment to their use is the need for specialized "mathematical" skills -- skills that most front-line software engineers do not have. Thus, we are investigating ways to make formal methods more directly suited for software development, in particular the design of distributed object software.

Summary of the Most Important Results

We proposed the idea of blending the formal capabilities of Petri nets with object oriented design concepts. Petri nets have the advantage of providing a theoretically mature and formal notation that is well suited for concurrent systems. But the Petri net model is very general-purpose. Object oriented design concepts aid the development of software architecture development and reuse. The new model that we have identified provides a domain-specific form of Petri net that is explicitly aimed at capturing the design of distributed object software systems. The underlying Petri net notation, upon which this new model is defined, allows for formal analysis of the resulting designs.

The design model that we have identified is called a State-Based Object Petri net (SBOPN). This model explicitly supports object concepts such as encapsulation, method activation, and inheritance. We have produced formal definitions for the SBOPN model and documents some simple example designs to illustrate the main features of this design notation. Since the SBOPN notation is based on Colored Petri nets, we have established a mapping from SBOPN models to standard Colored Petri net models. This implies that

SBOPN designs can make use of existing, or to-be-developed, Colored Petri net analysis techniques and tools.

We have created a basic scheme for inheritance modeling using the SBOPN notation. We identified and characterized the requirements for transformation of one SBOPN object model (a superclass model) into a new model (a subclass model) whose behavior is now restricted in terms of some of the methods. Most importantly, the new subclass model preserves the interface of the model from which it is defined. We introduced the idea of a "plug-in" structure (a sub-net) that can be added to an existing SBOPN object model. The plug-in acts as a controller on the behavior of the object model and restricts the activation of methods defined for the object. This provides for a way to synthesize subclass models due to restriction inheritance. We have defined such a synthesis algorithm and documented some illustrative examples of this concept. Finally, we have begun to work on the development of a prototype, web-accessible tool to demonstrate the creation and manipulation of SBOPN designs.

Finally, we revised and enhanced some earlier work involving the use of Petri nets to model Ada-based software. In particular, we documented examples of using the Petri net notation to model and analyze some cases of object synchronization in Ada-95. Also, we created compositional models for some of the key advanced tasking features of Ada-95 and illustrated how these models are evaluated using a particular type of Petri net analysis technique known as invariant analysis.

List of All Publications and Technical Reports

X. Xie and S. Shatz, "Instantiation of Colored Petri Nets for Distributed Object Modeling and Analysis," Submitted to *19th IEEE International Performance, Computing, and Communications Conference* (IPCCC 2000), Phoenix, Arizona, Feb. 2000.

H. Xu, R. Gedela, and S. Shatz, "Compositional Petri Net Models of Advanced Tasking in Ada-95," Submitted to *Computer Languages*.

R. Gedela, S. Shatz, and H. Xu, "Modeling of Synchronization Methods for Concurrent Objects in Ada 95," *Proceedings of the ACM Annual Conference on Ada* (Ada-99), Redondo Beach, Calif., Oct. 1999, pp. 211-220.

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